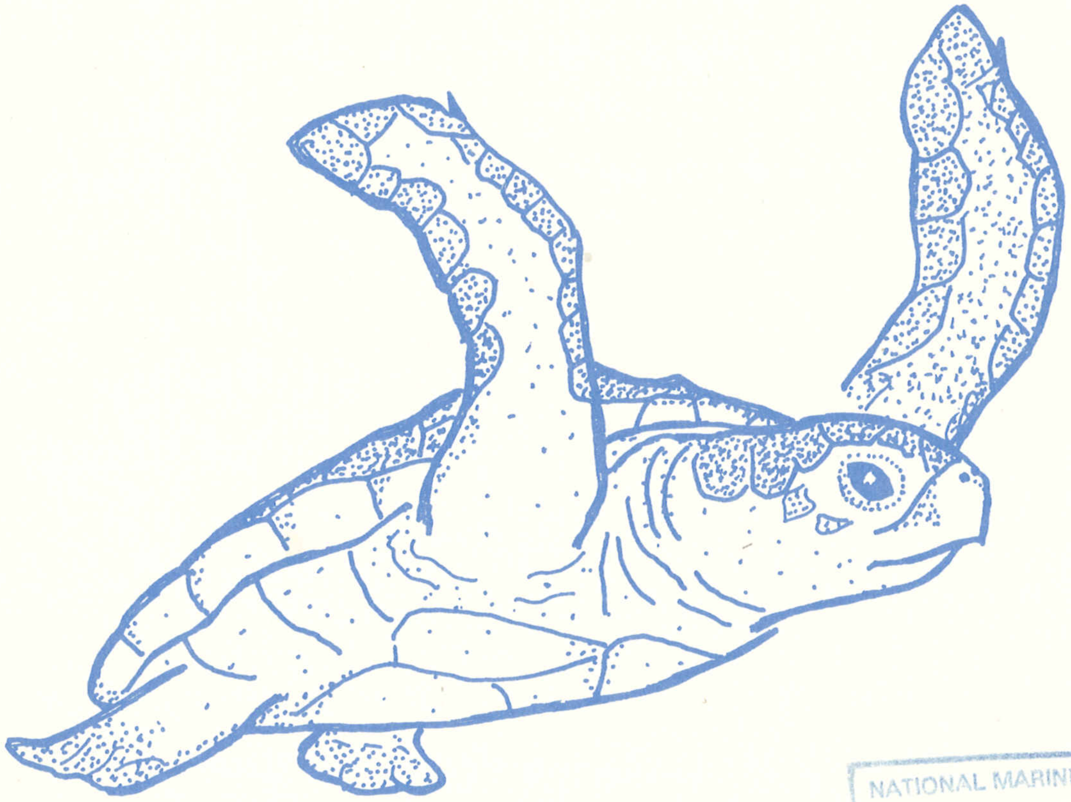
NOAA Technical Memorandum
NMFS-SEFC-200

WASTE CHARACTERIZATION STUDY FOR THE KEMP'S RIDLEY SEA TURTLE



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WASTE CHARACTERIZATION STUDY FOR THE KEMP'S RIDLEY SEA TURTLE

By

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U. S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Marine Fisheries Service
William E. Evans, Assistant Administrator for Fisheries

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

WASTE CHARACTERIZATION STUDY FOR THE KEMP'S RIDLEY SEA TURTLE

INTRODUCTION

The Kemp's Ridley sea turtle, Lepidochelys kempi is an endangered species. The National Marine Fisheries Service's Head Start program is part of an international operation to save the turtles from extinction. Under the Head Start program, eggs from the Ridley's only known wild nesting beach at Rancho Nuevo in Mexico are transported to Padre Island on the Texas coast to be hatched. The hatchlings are then reared in the National Marine Fisheries Service (NMFS), Southeast Fisheries Center, Galveston Laboratory, until the age of about one year before their reintroduction into the wild (Fontaine et al. 1985). This "head start" enables the turtles to develop a survival advantage.

The Galveston facility consists of 15 raceways, 20 ft. by 6 ft. by 2 ft., housed in two aluminum-framed green houses (Fontaine et al. 1985). One hundred and eight turtles are suspended in individual buckets in each raceway. The turtles are fed floating pellets individually by hand through the open top of the buckets. Uneaten food and excretions from the turtles fall through holes in the bottom of the bucket, ultimately coming to rest on the tank bottom. A batch, flow-through circulation system is currently used to maintain water quality. At intervals of approximately 48 hours, each rearing tank is manually drained, scrubbed, and refilled with fresh seawater which is maintained in heated storage tanks adjacent to the green houses. During these 48 hour cycles, the water in the turtle system can vary from very clean to, under the worst conditions, a black septic wastewater similar to a domestic sewage.

This system of rearing the young turtles can be highly effective; survival rates in excess of 90 percent have been reported in recent years (Fontaine and Caillouet, 1985). Intermittent replacement of water, however, has a number of drawbacks. The principal concern is the suspected relationship between the poor water quality in the system and the disease incidence in the animals. A number of the animals are under treatment for minor skin diseases at any given time. The nature of these infections suggest that they may result from high ammonia levels which can occur in the system at the end of the 48 hour cycle. Occasionally these diseases are fatal and lead to the loss of turtles.

This system of operation is extremely labor intensive. In addition, heating costs for replenishing water during the winter months are reportedly very high. Thus, it can be concluded that the cost effectiveness of the system can be improved. Finally, the current water treatment practice can result in water quality conditions which are not compatible with the high level of public exposure that this facility receives.

The limitations of the current water handling practices were recognized by the officials responsible for maintaining the turtles in the Galveston Laboratory. Mr. Clark T. Fontaine, Research Biologist at the Galveston Laboratory, initiated the efforts which led to the principal investigator's involvement in this project. In March of 1986, Dr. Malone and Dr. Mike Liffmann, Assistant Director of the Louisiana Sea Grant Program, visited the Galveston lab to observe the facility. At this time, the principal investigator had the opportunity to discuss the nature of the problem and research directions with Dr. Charles W. Caillouet, Chief of the Life Science Division of the NMFS Galveston

Laboratory Program. Arrangements were made for the research team to obtain permits for handling the endangered Ridley turtles, and for Mr. Fontaine to transport five turtles to Louisiana State University for study.

In April of 1986, five turtles were transported to an LSU laboratory equipped with closed, recirculating aquaculture systems for the purpose of conducting waste characterization research. The turtles were held in fiberglass tanks during the five months of study. Upon completion of the study, the turtles were returned to the Galveston facility and were subsequently released to the Gulf of Mexico in the early fall of 1986.

OBJECTIVES

The principal objective was to develop baseline waste characterization data required to design a wastewater treatment scheme for the Galveston Head Start facility. As a secondary objective, preliminary testing of some filtration components was undertaken to determine which units were most appropriate for inclusion in a wastewater treatment scheme. Finally, interim treatment recommendations were developed.

METHODOLOGY

Description of Prototype Holding System

Diagrams of the two fiberglass tanks and the biofilter system used to hold the five turtles during their stay in the LSU Civil Engineering Aquaculture Laboratory are shown in Fig. 1. Salinity ranged from 15 to 20 ppt throughout the study and was adjusted with Rila Marine Mix, an artificial sea salt. The system water was not changed during the five month period of study. Fresh tap water was added to compensate for

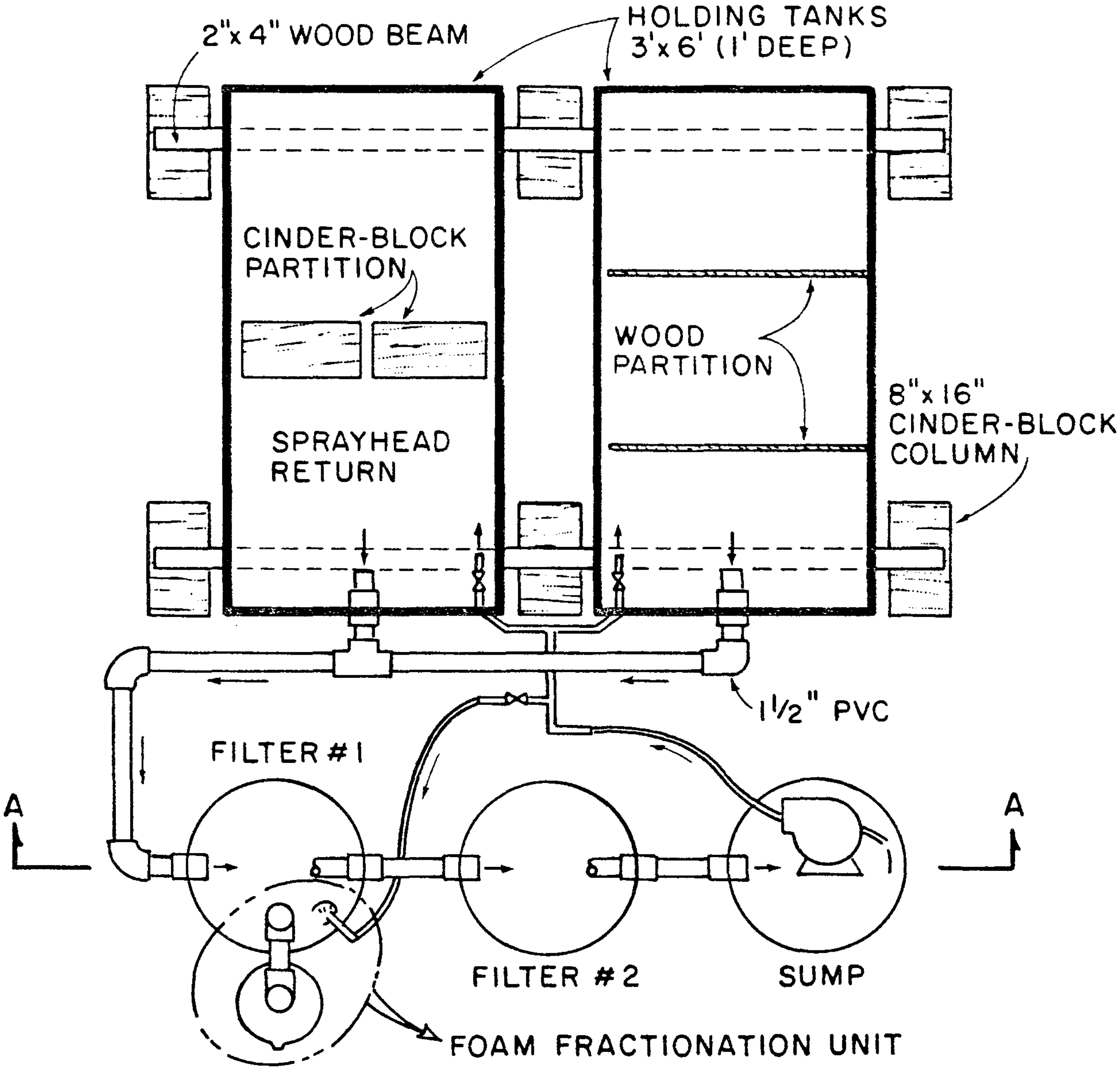
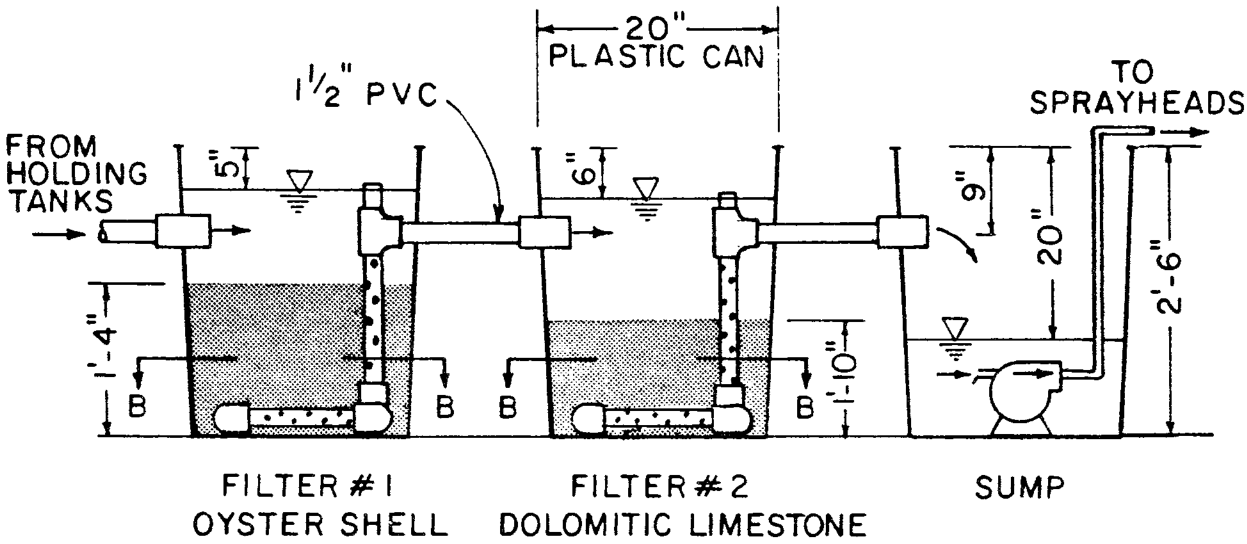


Fig. 1. Prototype holding system used at Louisiana State University.

losses due to evaporation and spillage. Water temperature was allowed to fluctuate with the room temperature of the lab, which ranged from 22 to 25 degrees Celsius.

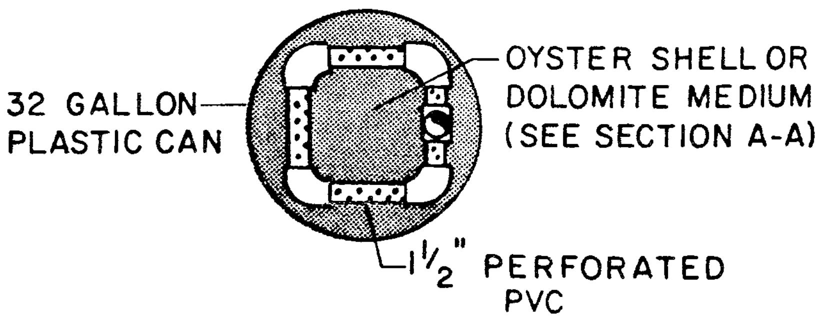
Water treatment was performed by flowing the system water through two sequentially connected downflow submerged rock filters (Fig. 2). The filters were constructed from 32 gallon plastic trash cans. Underdrains consisted of 1.5 inch PVC piping which was perforated with 3/8 inch holes. Each underdrain was connected to a vertical stand pipe which allowed for discharge to the top of the next sequential filter or sump. The stand pipe was open at the top to permit by-pass of water when flow down through the filter media was restricted. The first filter was filled with oyster shells which functioned primarily as a sediment trap. The loosely packed oyster shell bed had a high porosity and was highly resistant to clogging. The second filter was filled with a #67 grade (1/2 by 3/4 inch diameter) dolomitic limestone. The media in this filter contained sufficient surface area to provide for nitrification and biochemical oxygen demand (BOD) reduction (Manthe et al. 1983, 1984). The third component of the treatment system is a sump. A sump pump (Little Giant, Model 5-MSP, 0.1 hp) returned filtered water to the tanks, and provided a recirculation flow to a foam fractionator submerged in the first rock filter (Fig. 3). The foam fractionator effectively removed oils and greases that accumulated in the system.

The turtles were allowed to swim freely, but were separated from each other in the tanks. One of the six foot long tanks was partitioned into two 3 ft. long sections with cinder blocks, while the other was divided into three 2 ft. long sections by a wooden partition. The turtles were fed floating pellets, Purina Trout Chow, twice a day, at



* Note: Foam Fractionator Not Shown for Clarity

SECTION A-A
UNDERDRAIN ROCK FILTER SYSTEM



SECTION B-B

Fig. 2. Rock filter underdrain system used in conjunction with the holding system.

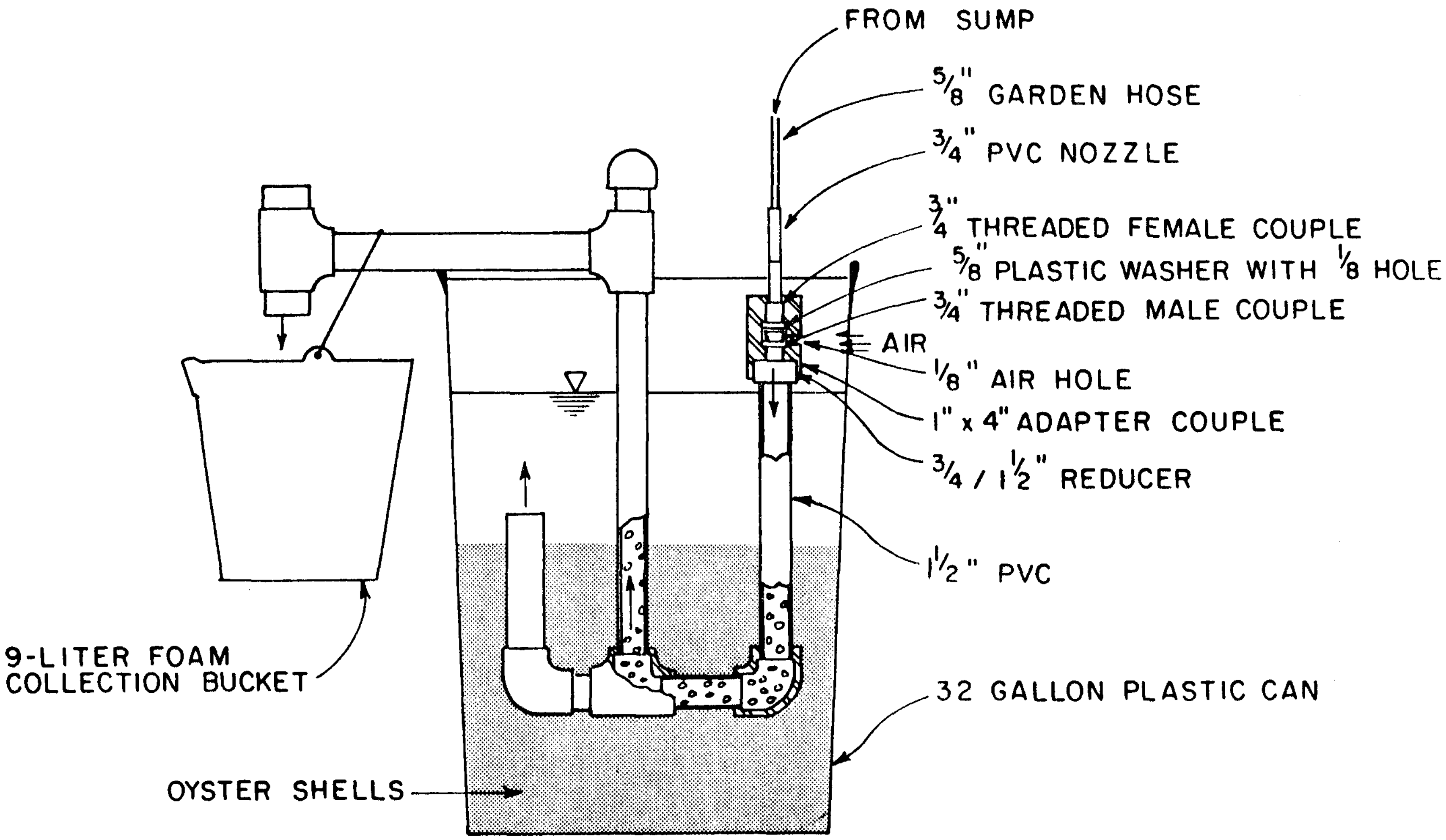


Fig. 3. Foam fractionation unit situated in the submerged rock filter.

9:00 a.m. and 5:00 p.m. They were allowed approximately thirty minutes to eat, after which time uneaten food was removed from the water. Intermittently, perhaps once or twice a week, the turtles were fed one to two live crayfish. The turtles received only indirect lighting from the overhead fluorescent lights in the lab. The photoperiod was limited to 10 to 12 hours per day. The lights were turned on manually, typically at 8 a.m., and turned off between 5 and 8 p.m.

Excretion Study

The waste characterization studies were undertaken to provide an estimate of the amount and character of waste excreted by the turtles in a 24 hour period. This was accomplished by placing the turtles in an isolated container of clean water. Chemical analyses of the water after the 24 hour period were used to quantify the amount of excretion.

A schematic showing details of the testing apparatus used to hold the turtles is illustrated in Fig. 4. The testing apparatus consisted of a plastic 32 gallon trash can filled with tap water. This reservoir served as a constant temperature water bath for the testing container, water temperature being maintained at 25 degrees Celsius by two aquarium type water heaters submerged in the can. The testing container was a circular plastic tub, 18 inches in diameter and 9 inches deep. The container was clamped to the sides of the garbage can to prevent tipping. Twelve liters of ammonia-free distilled water were placed in the tub, adjusted to a salinity of 20 ppt, and allowed to stabilize at 25 degrees Celsius.

During early testing attempts, several turtles moved from the main tanks to the testing tank appeared ill-adapted to the new environment. These turtles refused to eat, rendering experimental results suspect.

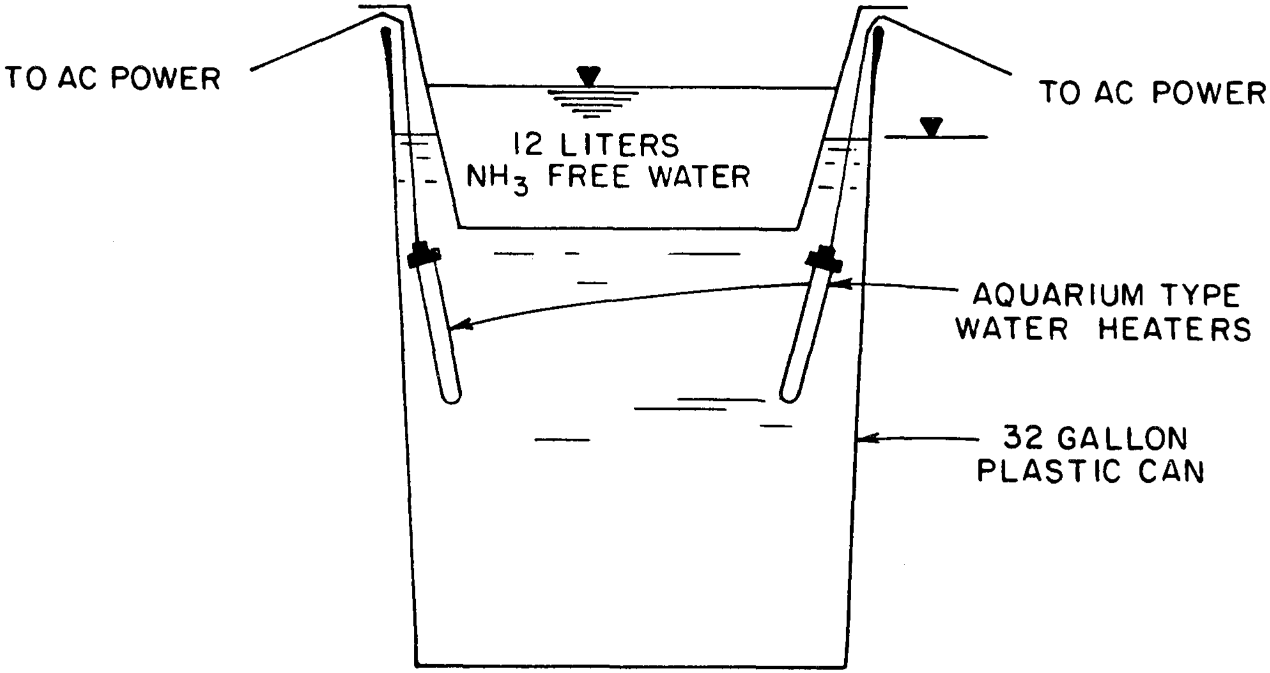


Fig. 4. Testing apparatus used with the waste characterization study.

For subsequent attempts, turtles were allowed to "warm up" in the main tanks by placing them in containers identical in size and color to the testing containers. The turtle to be tested was kept in this adjustment container until normal eating habits were observed and then placed under testing conditions.

At 1:00 p.m. on the day of testing, a turtle from the "warm up" tub in the main tank was removed and placed in the prepared test container. Initial temperature, pH, and salinity were recorded. At 5:00 p.m. on the test day, the turtle was fed a counted number of food pellets; thirty minutes later, uneaten food was removed and counted to determine the number of pellets eaten. This feeding process was again performed the following day at 9:00 a.m. At 1:00 p.m. on the following day, final pH was measured, the turtle was removed, weighed, and returned to the main tanks. Samples of the test water were taken for immediate chemical analysis.

Partitioning Study

A partitioning study was undertaken to determine the impact of suspended solids upon water quality. Selected samples from the excretion studies were split. One aliquot was examined unfiltered, while the other was pre-filtered through a 4.25 cm glass microfiber filter apparatus prior to analysis. Filtered samples were analyzed for BOD and total Kjeldahl nitrogen (TKN), and these values were compared to values obtained in the same tests on the unfiltered samples. The purpose of the partitioning study was to determine the maximum effect that inclusion of a solids settling unit in the treatment scheme could have on filtration efficiency.

System Monitoring

Periodically, a sample of water was withdrawn from the sump in the turtle holding system. These samples were immediately analyzed for BOD, total Kjeldahl nitrogen, ammonia nitrogen, and nitrite nitrogen. These samples were collected in the latter part of the study period after the system stabilized to represent typical system operation.

Chemical Methods

All data collected in these experiments was obtained from water quality tests performed according to procedures established in Standard Methods, 15th edition (APHA, 1980). Water quality parameters included in the excretion study were: biochemical oxygen demand, total Kjeldahl nitrogen, ammonia nitrogen, nitrite nitrogen, suspended solids, volatile suspended solids, and settleable solids. The value of each of these parameters in aiding filter design is summarized in Table 1. Techniques and instrumentation used to measure the above-mentioned parameters are presented in Table 2.

For the excretion study, approximately 5 liters of water was sampled for analysis after the 24 hour excretion period. Water quality tests were normally performed on the day of sample collection, with the exception of the distillation step of the TKN analysis, which was performed the following morning. The digested samples were kept on the digestion apparatus overnight. Also, suspended solids and volatile suspended solids tests were usually performed one or two days after the sample was collected; the preservation of sample for these tests was simply refrigeration. Suspended solids samples were filtered through glass fiber filters with a 0.45 micrometer pore size. Slightly larger sample volumes were taken for the partitioning and

Table 1. Water quality parameters included in the waste characterization study.

Parameter	Value
Biochemical Oxygen Demand	Sizing of biological filter, flow determination
Total Kjeldahl Nitrogen	Biological filter selection
Ammonia Nitrogen	Biological filter selection
Nitrite Nitrogen	Contributes to nitrogen mass balance analysis
Suspended Solids	Settling tank design
Volatile Suspended Solids	Biological filter solids balance
Settleable Solids	Settling tank design

Table 2. Water quality tests performed and instruments used (Standard Methods, 15th edition).

Water Quality Parameter	Test	Instrument
Ammonia Nitrogen	Distillation plus Nesslerization	Milton Roy Co. Spectronic 20 Spectrophotometer
Nitrite Nitrogen	Sulfanilamide-based colorimetric method	Spectronic 20
Total Kjeldahl Nitrogen	Digestion, Distillation plus Nesslerization	Spectronic 20
Biochemical Oxygen Demand	5-Day BOD Test	Fisher Accumet pH meter (Model 815 MP) with Orion Research Oxygen Electrode (Model 97-08-00)
Settleable Matter	Gravimetric Method	Imhoff Cone
Suspended and Volatile Suspended Solids	Nonfilterable Residue Method	Whatman 4.25 cm glass micro-fiber filters and filtration flask apparatus, drying oven, muffle oven, Mettler balance

system monitoring tests to compensate for the additional volume used for filtered analysis and lower dilution factors for the sump analysis. Each test for BOD, TKN, ammonia, and nitrite was performed by analyzing one blank, a standard, and two replicates of sample water. Each replicate was analyzed in triplicate. Values measured for standards were compared to standard curves for quality control of test results. Two standard curves were run, the second one performed when new reagents were prepared for depleted ones.

RESULTS

Behavior

The activity of the turtles during their captivity in the lab varied as the length of their stay increased. Early restlessness and anxiety exhibited by thrashing actions of the turtles waned after about one month. A noticeable behavior pattern that all five turtles exhibited was a desire to swim into the turbulent current caused by the spray head returning flow from the sump. Hours would be spent by these turtles "exercising" in this fashion. Otherwise, the turtles spent the daytime hours resting with their heads in the cinder block holes or under the wood dividers.

No major disease or health problems were perceived in any of the turtles; the only noticeable affliction was a minor skin abrasion on the front flipper of one turtle, which seemed to be healing fine at the time of the turtles' return to Galveston. The turtles usually showed vigorous appetites at both daily feedings, and enjoyed feeding on live crayfish that were given to them once or twice a week during the last two months. Based on their weight data, presented later, the turtles grew at a steady rate while in captivity.

Excretion Study

The results of water quality measurements made in the excretion study are presented in Tables 3 and 4. Table 3 shows results in total milligrams per day and Table 4 gives values in milligram per gram turtle mass per day, obtained by dividing values in Table 3 by the mass of the turtles at testing time. Information on the amount of food eaten during the 24 hour test period and turtle mass is made available in Table 5. Ground samples of the Purina Trout Chow were analyzed for BOD-5 (0.084 g-BOD_5/g-food) and TKN (0.33 g-N/g-food).

Thirteen separate data sets were collected on the five turtles during their stay. Ten of these tests yielded acceptable data. Three test samples analyzed early in the study were considered invalid because the erratic nature of the turtles' eating habits produced inconsistent test results. Subsequent testing attempts employed the adaption techniques discussed earlier to ease the transition to testing conditions.

Partitioning Study

Table 6 presents a comparison of filtered versus non-filtered values for the BOD-5 and TKN. The partitioning study was performed on samples of the final three turtles tested. A larger number of samples analyzed in this fashion would have been desirable, but results of these excretion study tests were fairly representative of the data on the remaining turtles.

System Monitoring

Table 7 displays the results of water quality tests performed on samples taken from the sump of the prototype holding system. Also listed is information on the turtle's weight during testing of the sump water. Flow rate through the filters varied from 5 to 8 gpm. Samples

Table 3. Results of the waste characterization study (mg/day).

Turtle Ident. Number (Date Tested)	Water Quality Parameter						
	Ammonia (mg-N/ day)	BOD-5 (mg-O/ day)	TKN (mg-N/ day)	Nitrite (mg-N/ day)	Susp. Solids (mg/day)	Volatile Susp. Solids (mg/day)	Settble. Solids (ml/day)
409 (6/4)	351.5	1474.8	631.1	0.940	6240.0	3773.3	25.2
410 (6/5)	507.2	2621.3	1021.5	0.163	12900.0	9360.0	58.8
417 (6/24)	430.8	657.6	776.4	35.9	3540.0	2304.0	51.6
410 (6/26)	399.6	924.0	757.2	27.7	3756.0	2328.0	74.4
420 (7/1)	505.2	1266.0	849.6	11.5	2904.0	1620.0	48.0
409 (7/3)	440.4	1050.0	626.4	15.7	2664.0	1620.0	45.6
423 (7/10)	451.2	594.0	638.4	34.8	2568.0	1380.0	54.0
409 (7/31)	375.6	795.6	636.0	39.1	1860.0	1584.0	46.8
410 (7/31)	519.6	908.4	726.0	0.276	1920.0	1668.0	22.8
417 (8/5)	345.6	878.4	548.4	40.9	1692.0	1356.0	36.0
	Statistics (mg/day)						
Average	432.7	1117.0	721.1	20.7	4004.4	2699.3	46.3
Std. Deviatn.	64.4	590.9	138.3	16.9	3395.6	2449.4	15.4
Coeff. of Var. (%)	14.9	52.9	19.2	81.6	84.8	90.7	33.3

Table 4. Normalized results of the waste characterization study (mg/g-day).

Turtle Ident. Number (Date Tested)	Water Quality Parameter						
	Ammonia (mg-N/ g-day)	BOD-5 (mg-O/ g-day)	TKN (mg-N/ g-day)	Nitrite (mg-N/ g-day)	Susp. Solids (mg/g-day)	Volatile Susp. Solids (mg/g-day)	Settble. Solids (mg/ g-day)
409 (6/4)	0.178	0.746	0.319	0.00048	3.16	1.91	0.013
410 (6/5)	0.213	1.099	0.428	0.00006	5.41	3.93	0.025
417 (6/24)	0.188	0.288	0.339	0.016	1.55	1.01	0.023
410 (6/26)	0.152	0.352	0.289	0.011	1.43	0.888	0.028
420 (7/1)	0.213	0.534	0.358	0.005	1.22	0.683	0.020
409 (7/3)	0.190	0.453	0.270	0.007	1.15	0.699	0.020
423 (7/10)	0.211	0.278	0.299	0.016	1.20	0.646	0.025
409 (7/31)	0.146	0.310	0.248	0.015	0.725	0.617	0.018
410 (7/31)	0.168	0.293	0.234	0.00009	0.620	0.538	0.007
417 (8/5)	0.128	0.327	0.204	0.015	0.629	0.504	0.013
	Statistics (mg/g-day)						
Average	0.179	0.468	0.299	0.009	1.71	1.14	0.019
Std. Deviatn.	0.030	0.266	0.066	0.007	1.49	1.06	0.007
Coeff. of Var. (%)	16.8	56.8	22.1	77.7	87.1	93.0	36.8

Table 5. Test conditions encountered during the excretion study.

Turtle Ident. Num.	Weight at Test Time (g)	Food Eaten (g)	Consumption (g/g)	Initial pH (of test water)	Final pH (of test water)
409	1977	23.6	0.012	8.8	7.1
410	2385	15.0	0.006	8.6	7.7
417	2287	15.2	0.007	8.5	7.4
410	2623	20.1	0.008	8.6	7.2
420	2373	13.9	0.006	not taken	7.6
409	2319	12.5	0.005	8.9	7.2
423	2136	9.2	0.004	8.9	7.3
409	2566	7.7	0.003	8.1	7.4
410	3098	12.6	0.004	8.2	7.4
417	2690	17.5	0.007	8.6	7.7
Average	2445	14.7	0.006		

Table 6. Comparison of non-filtered vs. filtered samples.

Sample Ident.	Turtle Identification Number/ Water Quality Parameter					
	409		410		417	
	TKN (mg/1)	BOD-5 (mg/1)	TKN (mg/1)	BOD-5 (mg/1)	TKN (mg/1)	BOD-5 (mg/1)
Non-Filtered	53.0	70.0	60.5	75.7	45.7	73.2
Filtered	38.3	12.7	50.8	8.1	39.8	22.4
Percent Removal	27.7	81.9	16.0	89.3	12.9	69.4

Table 7. Water quality tests on prototype holding system.

Water Quality Parameter	Date Tested				
	7/21	7/22	7/24	7/25	8/12
Temperature (Celsius)	24.5	24.5	24.5	24.5	23.0
pH	7.1	7.0	6.8	7.3	7.3
Salinity (ppt)	15	15	15	14	18
Turtle Mass in System (g)	10,735	10,735	10,735	10,735	14,890
BOD-5 (mg/l)	--	--	2.6	1.3	2.4
TKN (mg-N/l)	7.34	6.44	5.81	5.05	6.01
Ammonia (mg-N/l)	0.515	0.430	0.339	0.259	0.657
Nitrite (mg-N/l)	0.363	0.402	0.219	0.306	0.634

were taken from the sump on five days near the end of July and early August. The system held only four turtles in July while the fifth turtle was held in another system. The fifth sample was taken when all five turtles were in the system.

Initially, dolomitic limestone was used as filter media in both filters, but clogging problems developed early in the study due to solids loading. For this reason, the first filter of the double filter system was modified to hold oyster shells, which eliminated clogging difficulties. The visual quality of the water and filter performance deteriorated significantly when uneaten food was not removed from the water immediately after feeding. The system water developed a yellow tint during the final months, a minor annoyance considering that the water was not changed for the entire study period.

Otherwise, if uneaten food was promptly removed after feeding, the water was clear. No turbidity problems ever developed.

Summary

Figures 5 and 6 summarize the results of the waste characterization for the key water quality parameters of total Kjeldahl nitrogen (TKN) and BOD-5. These figures project the total waste loading in a typical rearing tank at the Galveston facility for the 1985 year class of turtles. These curves were constructed by combining the results of Tables 4-6 with unpublished data collected by Dr. Charles Caillouet on the growth pattern of the 1985 year class of turtles held in the Galveston lab. The growth curves for other year classes are similar (Caillouet and Koi, 1985). Dr. Caillouet provided the following equation relating turtle weight with age obtained by performing an overall lumped regression on 1985 data on turtle weights:

$$\ln(W) = \ln(1.95) + 0.299\ (T)^{\frac{1}{2}} \qquad (1)$$

where W is the turtle weight in grams and T is the turtle age in days ($n = 6{,}020$; $r^2 = 0.95$).

These figures dramatically illustrate the impact of increasing turtle age (and biomass) on the loading regime. The top curve represents total loading to the system assuming a 10 percent overfeeding rate. The middle curve estimates the loading in the system assuming 100 percent of the food presented to the turtles is consumed (the conditions under which the excretion studies were conducted). The bottom curve reflects the dissolved loading to the system assuming a mechanism for 100 percent removal of the suspended solids is implemented.

Several observations can be made by analyzing these loading curves. Filtration systems will become heavily loaded late in the year. The

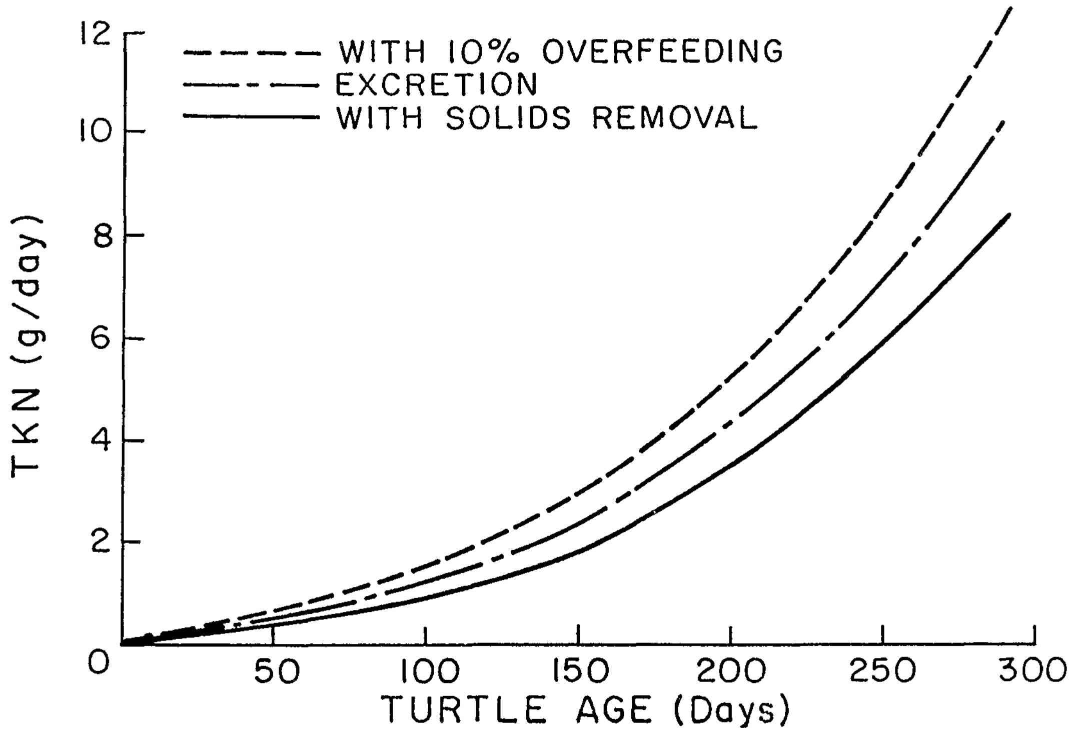


Figure 5. Total Kjeldahl nitrogen loading curves projected for 105 Kemp´s ridely sea turtles based upon average growth patterns for the 1985 year class (Caillouet and Koi, 1985) and mean weight normalized, nitrogen excretion rates derived from the yearling turtles.

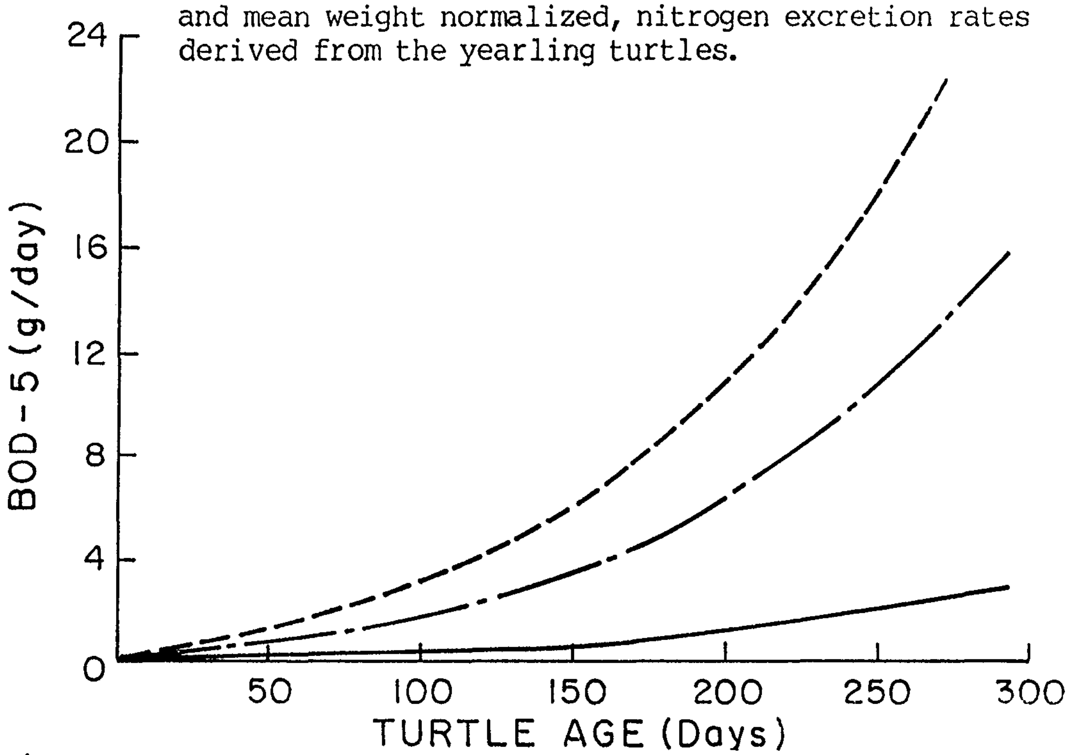


Figure 6. Projected biochemical oxygen demand loading curves for 105 Kemp´s ridely sea turltes based upon average growth patterns for the 1985 year class (Caillouet and Koi, 1985) and mean, weight normalized, nitrogen excretion rates derived from the yearling turtles.

exponential nature of BOD-5 and TKN loading with time displayed by the curves permits more than one raceway to be treated by a single filter early in the growth year. Additional filtration units can be brought on line as turtle size increases. Such optimization can result in significant energy savings.

Allowing uneaten food to remain in the system substantially increases the nitrogen loading, unnecessarily increasing ammonia loadings. Consequently, screens should be included in the filtration design to trap uneaten food for immediate removal after feeding. Figure 6 illustrates the dramatic reduction in BOD-5 loading that could be realized by including a solids removal unit ahead of the biological filtration units.

The high nitrogen levels remaining after solids removal revealed by the bottom curve of Figure 5 dictate the inclusion of a biological treatment unit. This unit should support nitrification of the toxic nitrogen forms of ammonia and nitrite to the relatively harmless nitrate. Submerged rock filters with a gravel or oyster shell media and fluidized sand bed filters are two economically feasible biological treatment units capable of supporting nitrification. However, clogging problems in the submerged rock filters due to excessive bacterial growth may make fluidized bed filters easier to maintain.

INTERIM DESIGN RECOMMENDATIONS

Additional research is needed to determine the best treatment scheme for the rearing tanks. Table 8 presents the functions of several treatment units considered for inclusion in the prototype filtration system. The research team was hesitant to recommend implementation of innovative treatment schemes without prior testing. Thus, the

Table 8. Treatment components considered for inclusion in the Ridley turtle treatment system.

Component	Function
Screen Separator	Removal of uneaten food pellets
Settling Tank	Solids removal
Rapid Sand Filter	Solids removal
Submerged Rock Filter	BOD and ammonia oxidation
Fluidized Bed Reactor	BOD and ammonia oxidation
Trickling Filter	BOD and ammonia oxidation
Foam Fractionator	Removal of oils and greases, aeration
Ozonation	Bacterial reduction, color removal, oxidation of refractory compounds

interim, a design employing submerged rock filters similar to those used in the experimental system is provided along with suggestions for an improved raceway design. The prototype design will adequately treat recirculated waters, but more cost efficient treatment schemes can be developed with further research. Installation of the prototype design is only recommended as an interim measure until more effective designs can be developed. The prototype system will provide the Galveston staff operational experience with a closed system. This experience will demonstrate the potential benefits of closed system operation, allowing development of sound recommendations for full scale implementation.

Significant benefits could be realized by improving the hydraulic configuration of the rearing tanks. A critical function of flow through the raceway is removal of solids and uneaten food. This function can most efficiently be achieved by creating a serial flow pattern. Serial flow can be accomplished by adding partitions in the rearing tanks, such as presented in Figure 7, which illustrates a conceptual raceway design capable of rearing 78 turtles. Maintaining a sufficient transport velocity through the partitions for solids removal will be performed by the slotted partition design as detailed in Figure 8. Forcing the system flow through areas of small cross sections will create conditions of high velocity flow capable of transporting floating food pellets through the top slots and settled solids through the holes at the partition bottoms. Dimensions for slots have been estimated and may require further refinements to assure head losses through the raceway are not excessive.

By decreasing the pump's flow rate, water level in the raceway for normal operation and during feeding can be kept below the slots in the partition tops. This flow will keep food within the partitions during feeding periods and also maximize velocities for settled solids removal through the bottom holes. Immediately following feeding, flushing the system to remove uneaten floating flood can be accomplished by increasing the flow rate to raise the water level over the top slots. Figure 9 shows raceway outlet details which features a PVC standpipe apparatus. This apparatus drains system water through the bottom 2 inch pipe during normal operation and allows overflow through the top 4 inch pipe for flushing operations. The fittings within the turtle tank should not be glued until the hydraulic operation of the raceway is confirmed. The size of the reducer for the lower overflow pipe may require adjustment.

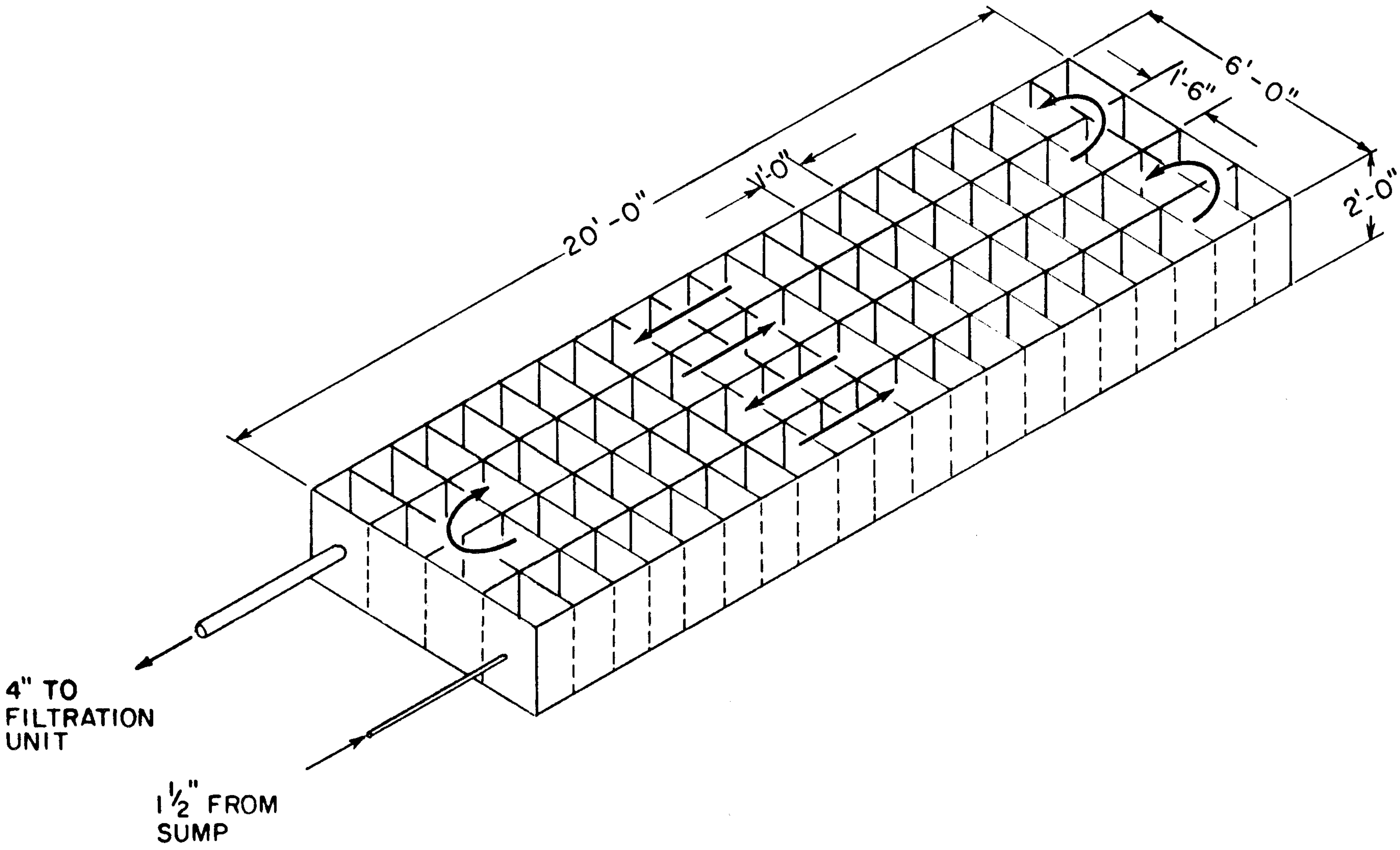


Fig. 7. Conceptual design of a partitioned turtle raceway system.

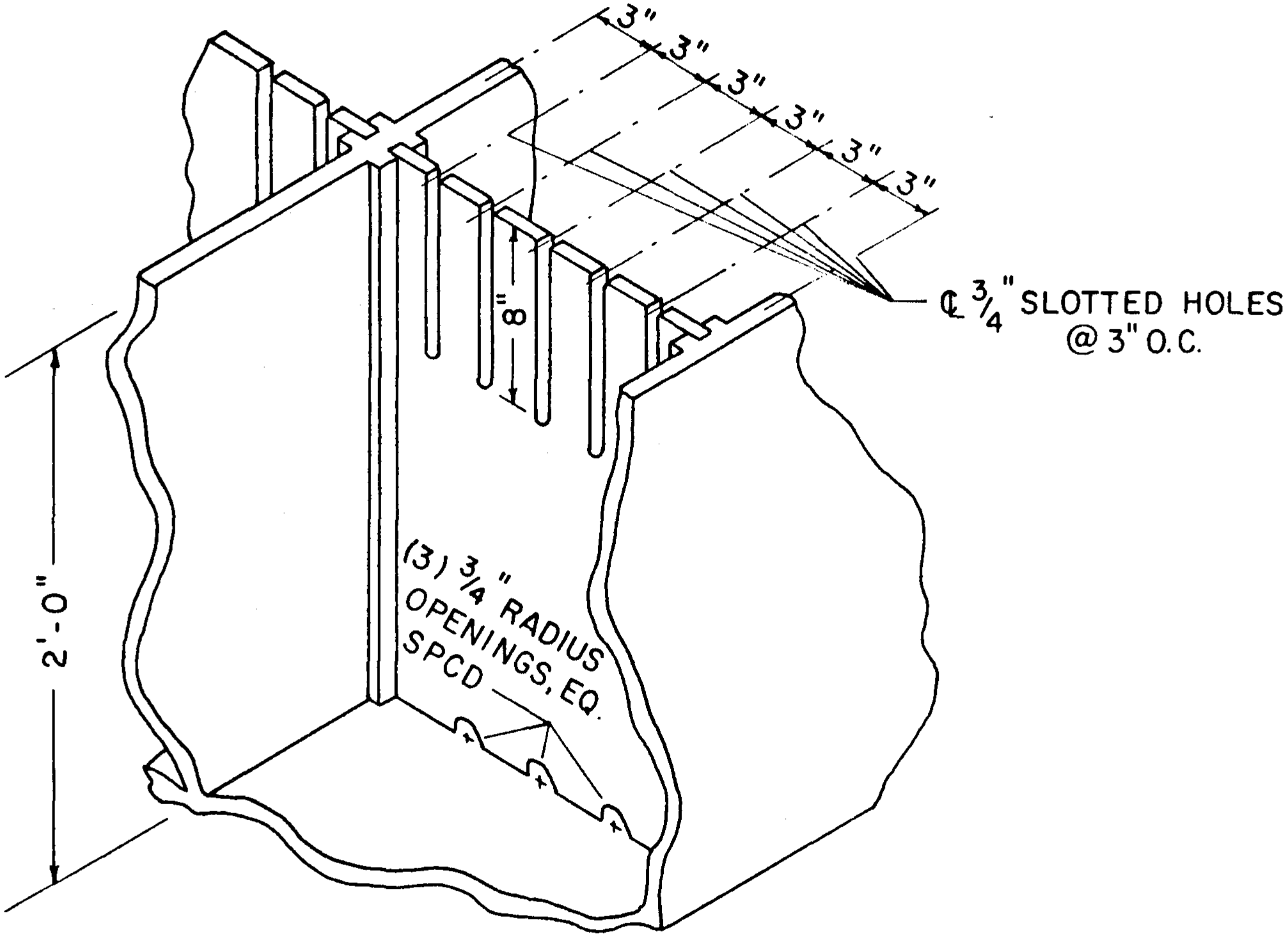


Fig. 8. Typical turtle compartment within the partitioned raceway system.

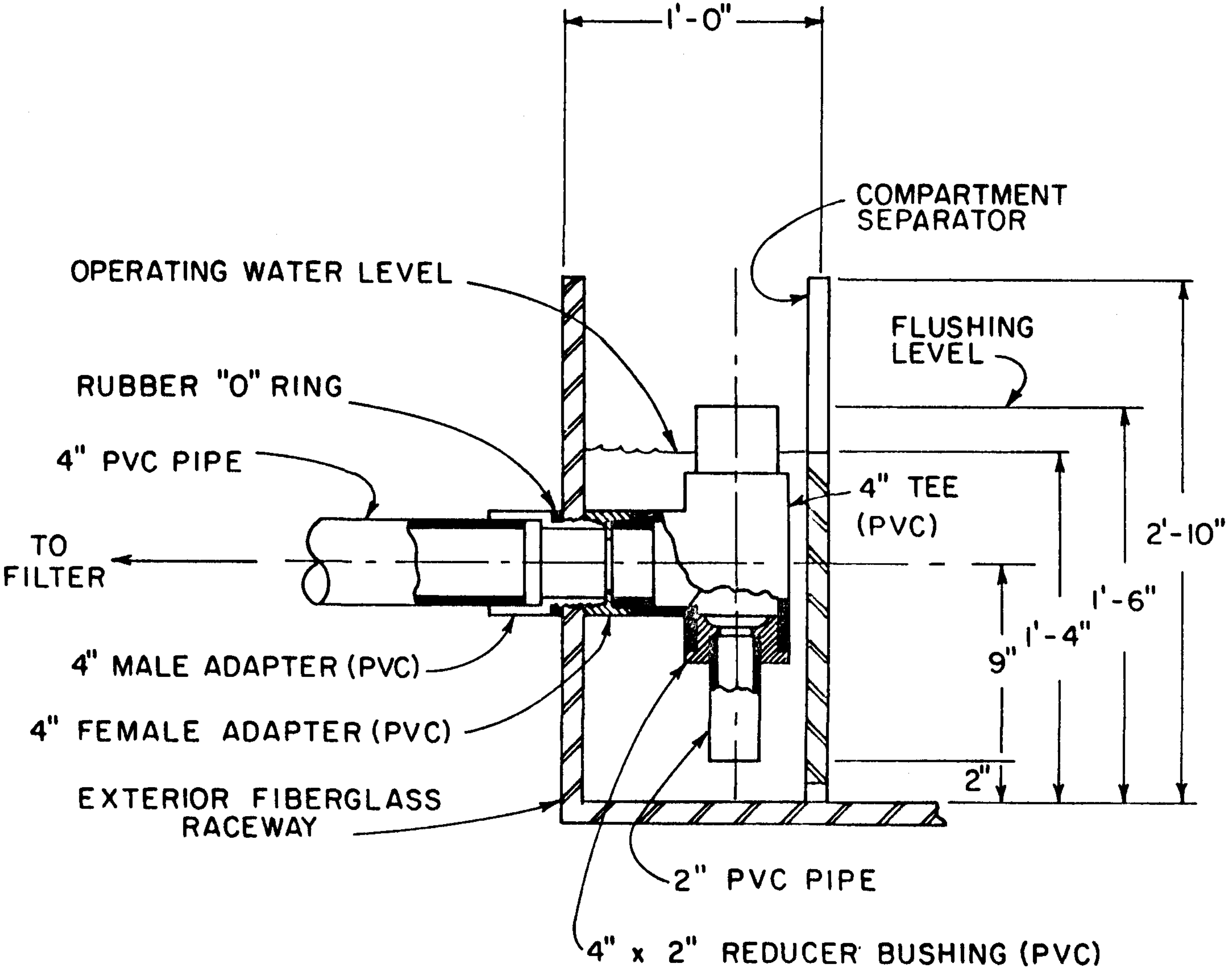


Fig. 9. Outlet detail in the partitioned raceway system.

Filtration will be performed by two sequentially connected submerged rock filters (Spotte, 1979; Wheaton, 1977), oyster shells being used for media in the first filter and #67 dolomitic limestone used in the second filter, followed by a sump tank for dilution volume and pump intake. Three 60 cubic foot tanks available at the Galveston lab will be used for filter and sump tanks (Figure 10). The oyster shell filter will act as a solids trap. To prevent filter clogging, annual breakdown of the filter will be required to remove accumulated solids. For this reason, the researchers recommend that the oyster shells be loosely packed in plastic tubular netting such as Duronet (TM), manufactured by Naltex of Texas, so that the netted shells can be easily removed from the filter and rinsed free of solids. Whole oyster shells should be placed loosely in bag nets so that adjacent bags will conform closely to each other. Gaps between tightly filled bags would cause the filter to short circuit defeating its solids removal function. Small bags should be used for easy handling.

Figure 11 shows details of the filter design, underdrain system, and piping. The first filter requires a minimum volume of 37 cu. ft. of rinsed oyster shell media for a 108 turtle system, representing a 2.5 ft. depth of shells in the 60 cu. ft. tank. The loosely packed tubular netting is placed on top of the PVC underdrain system. A 90 degree 4 in. PVC elbow, placed on the end of the raceway outlet pipe, will empty onto the oyster shell filter. The screening device for solids removal should be placed at the pipes' end to screen raceway effluent to the filter. The screening device could be constructed by placing a rectangular wooden frame lined with a fine mesh nylon screen under the effluent pipe's discharge, as shown in Figure 11. Daily

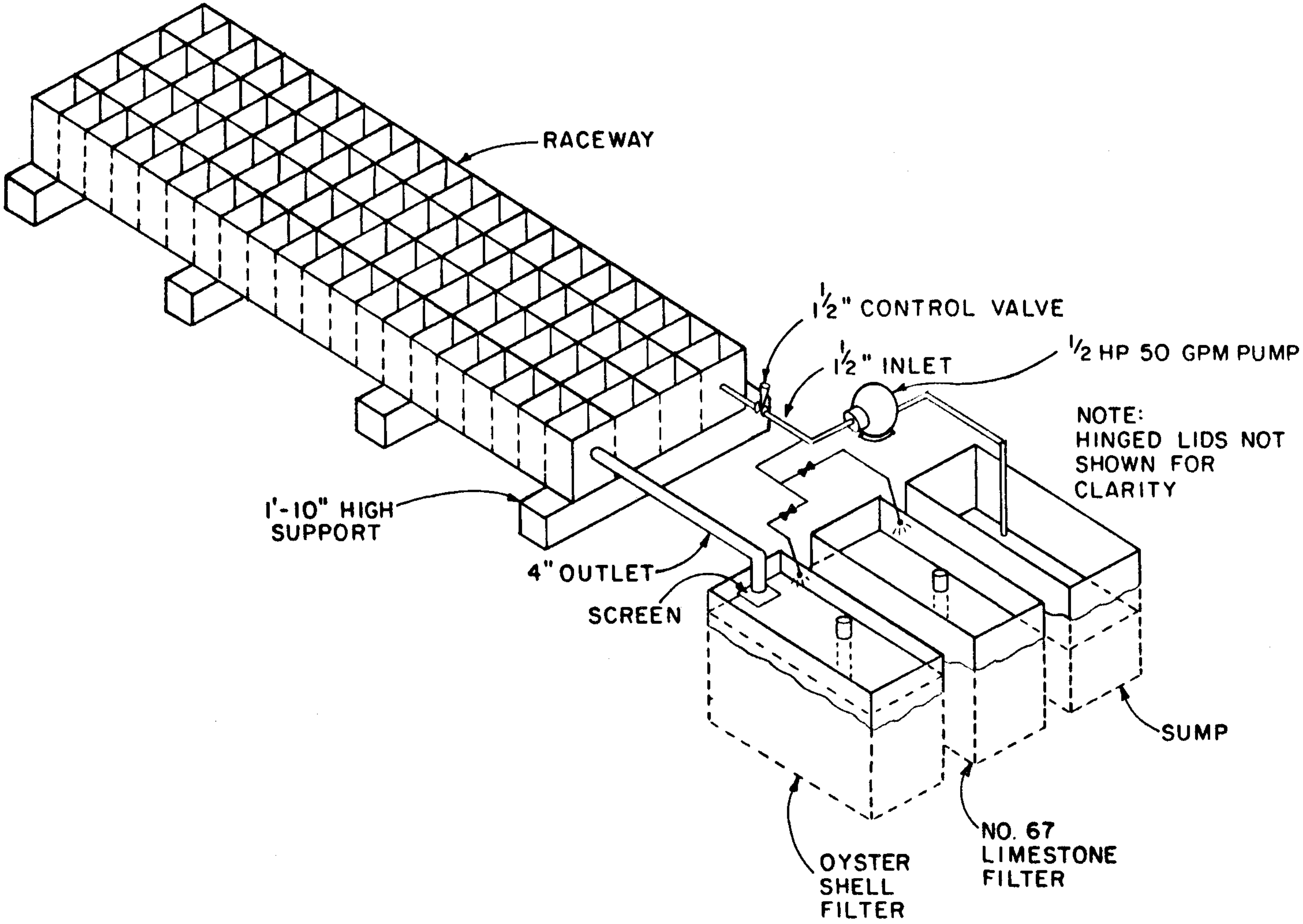
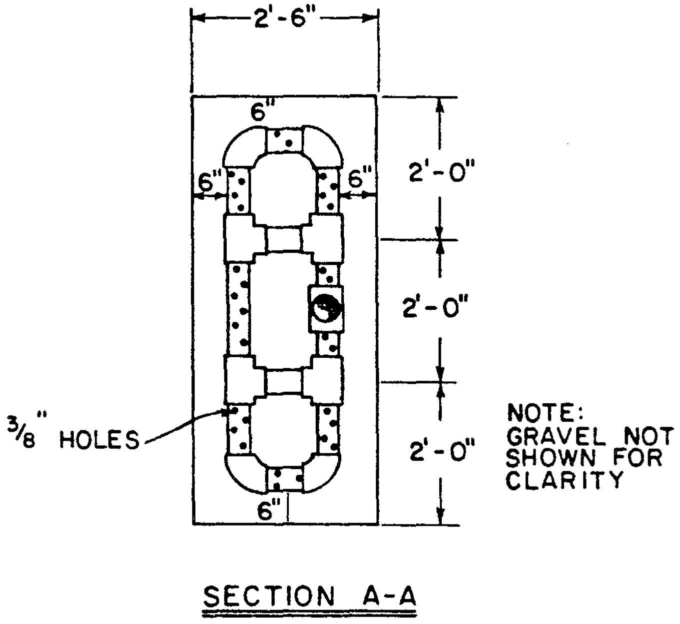


Fig. 10. System layout for the proposed raceway.



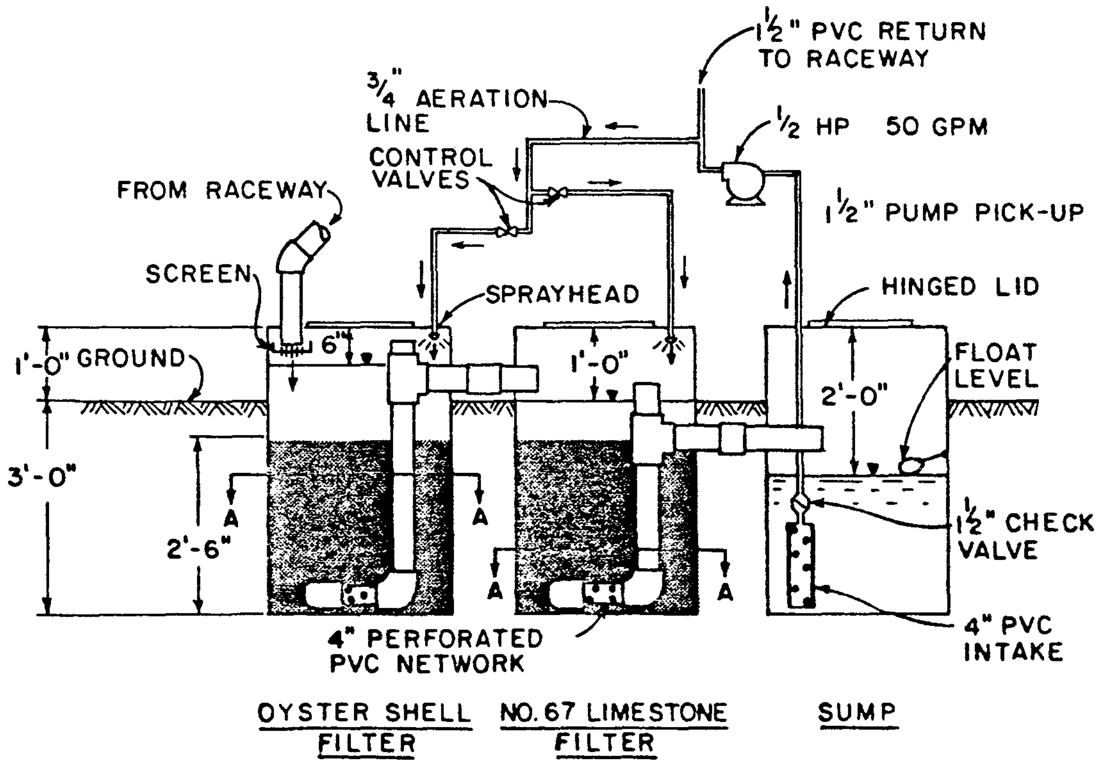


Fig. 11. Details of the filter design, underdrain system, and piping required for the proposed raceway system.

removal of the screening device for emptying solids captured after feeding can easily be accomplished.

The underdrain system consists of perforated 4 in. PVC pipe as shown in section A-A of Figure 11. Pipe fittings do not require gluing. Holes, 3/8 in. diameter, should be drilled evenly spaced over the entire surface of the 4 in. PVC pipe. The standpipe is non-perforated and functions during normal operation as an effluent pipe for filtered water passing through the bed. Should clogging conditions develop, the standpipe provides for bypass to the second filter. The effluent of the oyster shell filter will freely empty onto the water surface of the second filter.

The second filter contains #67 dolomitic limestone and serves as a mechanism for nitrification and BOD reduction. The third tank acts as a sump for dilution volume, storage for surge volume when the pump is not operating, and pump intake reservoir. The tanks may be buried to protect system water temperature from seasonal temperature extremes. It is recommended that the tanks be buried to 3/4 of tank depth. Hinged lids should be attached to the tops of all tanks for safety purposes.

The second filter will require a minimum of 33 cu. ft. of rinsed dolomitic limestone media for a 108 turtle system, representing about a 2.5 ft. depth in the 60 cu. ft. tank. The filter will perform better if the #67 limestone is sifted through hardware cloth to remove stones less than 1/2 inch in diameter. The smaller stones can cause premature clogging of the filter bed. The gravel should be placed on top of the filter's underdrain system which is similar to the first filter. Upon exiting the second filter, flow will empty onto the water surface of the sump.

As shown in Figure 11, the sump will contain the pump intake strainer, which will be constructed of 4 in. perforated PVC pipe. A 1.5 in. reducer will be fitted to the 4 in. strainer for reduction into the 1.5 in. pump intake pipe. A 1.5 in. check valve shall precede the pump to prevent loss of pump prime should the pump be turned off. A float valve should be placed on the reservoir's side to replace water lost from evaporation. This float valve should be connected to a fresh water source. A 1/2 horsepower self-priming pump capable of providing a flow rate of 50 gallons per minute is recommended for installation.

The recirculation line returning filtered flow to the raceway will consist of a 1.5 in. PVC pipe fitted with a 1.5 in. ball valve placed near the raceway influent for controlling pump flow rate to the raceway. A 3/4 in. aeration line with 3/4 in. control valves will be fitted to the 1.5 in. raceway recirculation line and will send return flow to both filters to provide increased filtration and aeration of system water. Three 1/8 in. diameter holes should be drilled into the PVC caps attached to the ends of the 3/4 in. aeration lines. Recirculated flow will spray onto the water surface of both filters, achieving the aeration needed for oxidation of the wastewater.

Operation and Maintenance Guidelines

The 1.5 in. control valve placed in the raceway recirculation pipe will be located near the raceway influent for convenient flushing operation following feeding. During normal operation, water level in the raceway should be kept just below the slots in the partition tops to provide maximum velocity of flow through holes in partition bottoms for efficient removal of settled solids. Immediately following feeding, the control valve should be adjusted to raise the raceway level above the bottom of the top slots to facilitate removal of the uneaten floating food pellets. When flushing is complete, water level should be returned to the original level by adjusting the control valve. Uneaten flood and settled solids will be flushed onto the screening device located under the raceway effluent pipe in the oyster shell filter. The screen should be checked daily for solids accumulation and emptied when appropriate.

The 3/4 in. control valves on the aeration lines should be adjusted to maintain enough flow for aerating of the filter water while allowing sufficient flow through the 1.5 in. recirculation line for raceway flow requirements. Oxygen levels in the effluents from filters #1 and #2 must remain above 2.0 mg/l. Failure to maintain effluent oxygen levels above 2.0 mg/l will lead to system failure. The nitrification bacteria responsible for ammonia and nitrite oxidation are strict aerobes (Manthe et al. 1984). Rapid buildups of ammonia and nitrite will occur if oxygen levels are not maintained. Oxygen levels in the filters are controlled by the total volume of water passing through the filters (Manthe et al. 1985) and by the vigor of the aeration action induced by the spray heads. If temporary excess flow is needed for raceway operations, the aeration flow may be temporarily reduced to permit the full flow to reach the raceway.

The biological filters must be permitted to acclimate for 30-45 days to the loading regime before they will contain sufficient bacteria populations to assure treatment (Malone and Manthe, 1985). If unacceptable water quality conditions develop during this acclimation period, the water in the system should be replaced with fresh sea water. Once acclimated, water quality in the system should be consistently good. Ammonia and nitrite levels should remain below 1 mg-N/l. BOD-5 levels should be below 5 mg/l. The water should be clear, although it may yellow with age as refractory dissolved organic accumulate.

The only drawback to the submerged rock filters is its tendency to clog. In the first filter, the oyster shell filter, this will most likely occur as the result of a long term accumulation of refractory solids. Should oyster shells in the first filter become clogged, wastewater flow will be bypassed to the second filter overflow into the first filter's standpipe. As soon as the first filter bypasses, the netted shells should be removed and rinsed. If clogging conditions develop in the second filter, overflow will be diverted by its standpipe into the sump. Clogging of the second filter can be expected during periods of very high loading. If water quality remains acceptable, no action need be taken. If system water quality becomes unacceptable, the second filter should be broken down by removing limestone gravel for rinsing of both the gravel and PVC underdrain system.

The filtration system presented here will effectively control planktonic algal growth. The system will not, however, discourage the growth of attached algae on the turtles' backs or on the side walls of the raceway system. It is suggested that the growth of attached algae will be best controlled by shading the raceway so that the light intensity is below that required for the algae's proliferation. No algae problem was observed in the LSU prototype system. The turtle tanks received only indirect flourescent lighting. Growth of attached algae in the filter boxes is not harmful. Excessive growths may require removal if they interfere with the pump intake in the sump.

Filter design was performed for a single existing raceway of 108 turtles for immediate implementation to existing rearing facilities;

however, overdesign of the system will permit additional loading should filter performance prove satisfactory for one raceway. The loading of a single raceway theoretically represents only one-half of the filtration system's capacity. If improved raceways are constructed following the raceway design of Figure 7, the filter should be capable of treating wastewater from at least two raceways filled with yearling turtles. Filter design was based on a worst case analysis utilizing waste characterization data and maximum observed weight (2.5 kg) collected on the LSU lab animals. Weights of the LSU animals were significantly higher than weights predicted by Dr. Caillouet's weight formula for the 1985 class (eq. 1) so an additional safety factor is provided for most of the year.

CONCLUSIONS

1. The Kemp's Ridley turtles can be successfully held for extended periods of time in closed or semi-closed recirculating systems without any adverse impact.
2. The nitrogen excretion rate of the Kemp's Ridley turtle was a relatively constant 0.3 mg-N/gm turtle-day. Ammonia was the principle nitrogen excretion product found in the water at the end of a 24 hour period.
3. Due to the high nitrogen content of the Purina floating trout food fed to the turtles, uneaten food has a major impact on the nitrogen loading to the system. Overfeeding must be avoided or excess food rapidly removed if ammonia and nitrite levels are to be successfully controlled.

4. The BOD-5 excretion rate was highly variable, averaging nearly 0.5 mg/gm turtle-day. The BOD-5 loading rate to the system is controlled by the solid excretion rate to the system.
5. The high solids loading rate and associated BOD suggest that an effective solids removal mechanism included in the treatment system for the recirculating system would greatly improve filter efficiency and increase filter loading capacity.
6. Submerged rock filters would provide nitrification sufficient for the recirculation system, but may require periodic breakdown to remove accumulated solids.
7. There are no insurmountable technical obstacles to developing a completely automated rearing system providing for automatic feeding, heating, lighting, water exchange and water quality treatment for the turtles.

RECOMMENDATIONS

1. It is recommended that this research effort be continued. There appear to be no serious obstacles to using recirculating systems for rearing of the Kemp's Ridley sea turtle.
2. Selected findings of this initial study need to be reconfirmed. Additional testing of the food and additional partition studies should be undertaken to assure findings in these areas are statistically sound.
3. At least one of the rearing tanks at the Galveston lab should be converted to a recirculating format this spring, implementing the interim prototype treatment system design in this report. This system should be monitored and evaluated by the Galveston staff.

4. A fully automated prototype rearing system employing the most advanced design concepts should be set up on the LSU campus for testing and refinement. Following evaluation, selected components of this unit will be installed on a second rearing tank at the Galveston lab for staff evaluation.
5. An analysis of the cost and benefit of the selected treatment and automation options should be undertaken by the research team.
6. Recommendations for a permanent full scale implementation should be developed by the Galveston lab staff working in collaboration with the research team following evaluation of the prototype systems.

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LITERATURE CITED

APHA. 1980. <u>Standard Methods for the Examination of Water and Wastewater</u>. 15th Edition, American Water Works Association, Water Pollution Control Federation, and American Public Health Association, Washington, D.C., USA.

Caillouet, C. W., and D. B. Koi. 1985. Patterns and variability in the first year growth in the weight of captive-reared Kemp's Ridley sea turtle: a graphical analysis. NOAA Tech. NMFS-SEFC-164, 4 pp. + 52 figs.

Fontaine, Clark T. and Charles W. Caillouet, Jr. 1985. The Kemp's ridley sea turtle head start research project: an annual report for fiscal year 1984. NOAA Technical Memorandum NMFS-SEFC-152, ii plus 13 p. and 3 tables.

Fontaine, C. T., K. T. Marvin, T. D. Williams, W. J. Browning, R. M. Harris, K. L. Indelicato, G. A. Shattuck, and R. A. Sadler. 1985. The husbandry of hatchling to yearling Kemp's Ridley sea turtles (<u>lepidochelys</u> <u>kempi</u>). NOAA Tech. Mem. NMFS-SEFC-158, 24 pp.

Malone, R. F., and D. P. Manthe. 1985. Chemical addition for accelerated nitrification of biological filters in closed blue crab shedding systems. Pages 41-47 <u>in</u> National Symposium on the Soft-Shelled Blue Crab Fishery, H. M. Perry and R. F. Malone (eds.).

Manthe, D. P., R. F. Malone, and H. M. Perry. 1983. Water quality fluctuations in response to variable loading in a commercial closed blue crab shedding facility. Journal of Shellfish Research, 3:175-182.

Manthe, D. P., R. F. Malone, and S. Kumar. 1984. Limiting factors associated with nitrification in closed blue crab shedding systems. Aquacultural Engineering, 3:119-139.

Manthe, D. P., R. F. Malone, and S. Kumar. 1985. Elimination of oxygen deficiencies associated with submerged rock filters used in closed, recirculating-aquaculture systems. Pages 49-55 _in_ National Symposium on the Soft-Shelled Blue Crab Fishery, H. M. Perry and R. F. Malone (eds.).

Spotte, S. 1979. _Fish and Invertebrate Culture, Water Management in Closed Systems_. 2nd Edition, Wiley-Interscience, New York, USA, 177 pp.

Wheaton, F. W. 1977. _Aquacultural Engineering_. Wiley-Interscience, New York, USA, 708 pp.